# TRANSIT

The November 2013 Newsletter of

Cleveland & Darlington Astronomical Society

**<u>NEXT TWO MEETINGS, each at 7.15 pm at Wynyard Planetarium</u>**

**Friday 8 November 2013**

**Massive stars: can they explode more than once?**

**Prof. René Oudmaijer, *Astrophysics Group, University of Leeds***

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**Friday 13 December 2013**

***Astronomy at the end of the rainbow***

**Prof. Paula Chadwick, *Reader, Dept. of Physics, Durham University***

## Content

## Editorial

*Rod Cuff*

I'm afraid this issue has few items in it, at least partly because I've been very pushed for time (I'd planned to write at least one article myself). Apologies – I trust December's will be fuller. In the meantime, please enjoy such goodies as more of Keith Johnson's amazing astrophotos and part 2 of Ray Brown's articles on gravitation – challenging for some, I know, but very worth your while to get to grips with.

Alas, CaDAS had to cede the Thomas Wright Trophy to Durham A.S. this year – well done, Durham! Next year, guys, next year … Michael Roe, who was to be a CaDAS team member, was unable to get to the venue at the relatively last minute, and since Michael has the trophy at home, it has not yet been formally passed over to Durham. This should be remedied at this month's meeting on Friday 8 November.

Many thanks to all contributors. Please let me have articles for December's *Transit* by 28 November if possible.

*Rod Cuff,* info@cadas-astro.org.uk *1 Farndale Drive, Guisborough TS14 8JD*
*(01287 638154, mobile 07775 527530)*

## Letter

### Alan Bean's visit

*from Pat Duggan*

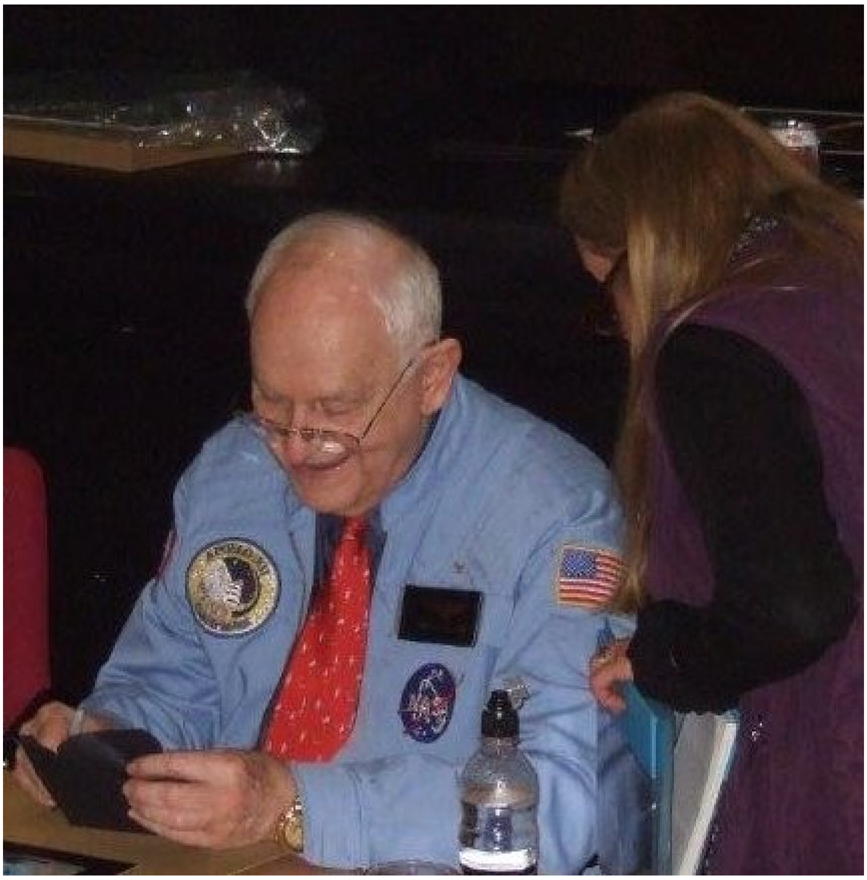
Alan Bean was the third man to set foot on the Moon and was in this country recently visiting schools in the Pontefract area. The visit was arranged by Ken Willoughby and funded by the sale of lecture and dinner tickets as well as an auction of space-travel memorabilia. I was part of an audience (*see the photo on the next* page) that had travelled to meet him from as far away as Cornwall and the further reaches of Scotland. It was a most enjoyable function.

Alan gave a most energetic lecture lasting two hours, all about his career with NASA and the motivation to record his amazing journey to the Moon in art. He was convinced that his experience had been so rare – to have been one of only twelve men to walk on the Moon – that he felt driven to portray the vistas that so few had seen and to show them to as many people as possible here on Earth.

He admitted that the craft of painting is a skill that had not been very easy for him to learn at first. He makes his artwork unique and genuine by stamping moonboot prints into the canvas coating before he begins applying colour. His pictures each contain a thread or two of his own Apollo insignia badge from his pressurised suit that became impregnated with dust from the surface of the Moon while he was working there. His works sell for many thousands of dollars and are satisfying to him as a sharing of his own great 'Moon Experience'.

His thoughts on first placing his foot on the Moon surface were not, as Armstrong's had been, 'One small step...' but actually, 'Oh no, only 20 minutes to complete all the tasks NASA has set for today'! He regrets having had so little time to take in the silence and the surroundings.

*Best wishes – Pat*



## OBSERVATION REPORTS AND PLANNING

### Websites – November 2013

Here are some suggestions for websites that will highlight some of what to look out for in the night sky in November.

- **HubbleSite**: a **video** of things to see each month:

  http://hubblesite.org/explore_astronomy/tonights_sky

- **Night Sky Info's** comprehensive coverage of the current night sky:

  www.nightskyinfo.com

- **Jodrell Bank Centre for Astrophysics** – The night sky:

  www.jodrellbank.manchester.ac.uk/astronomy/nightsky

- **Telescope House** monthly sky guide:

  http://tinyurl.com/pzzpmsx

- **Orion's** What's in the Sky – November:
  www.telescope.com/content.jsp?pageName=In-the-Sky-this-Month

- **Society for Popular Astronomy's monthly Sky Diary**:

  www.popastro.com/documents/SkyDiary.pdf

## The Sun and M31

*Keith Johnson*

*[Keith continues, month after month, to produce some of the best amateur astrophotography in the UK. Here are a couple of his recent images, of the Sun in Hα light and of M31, the Andromeda Galaxy. – Ed.]*

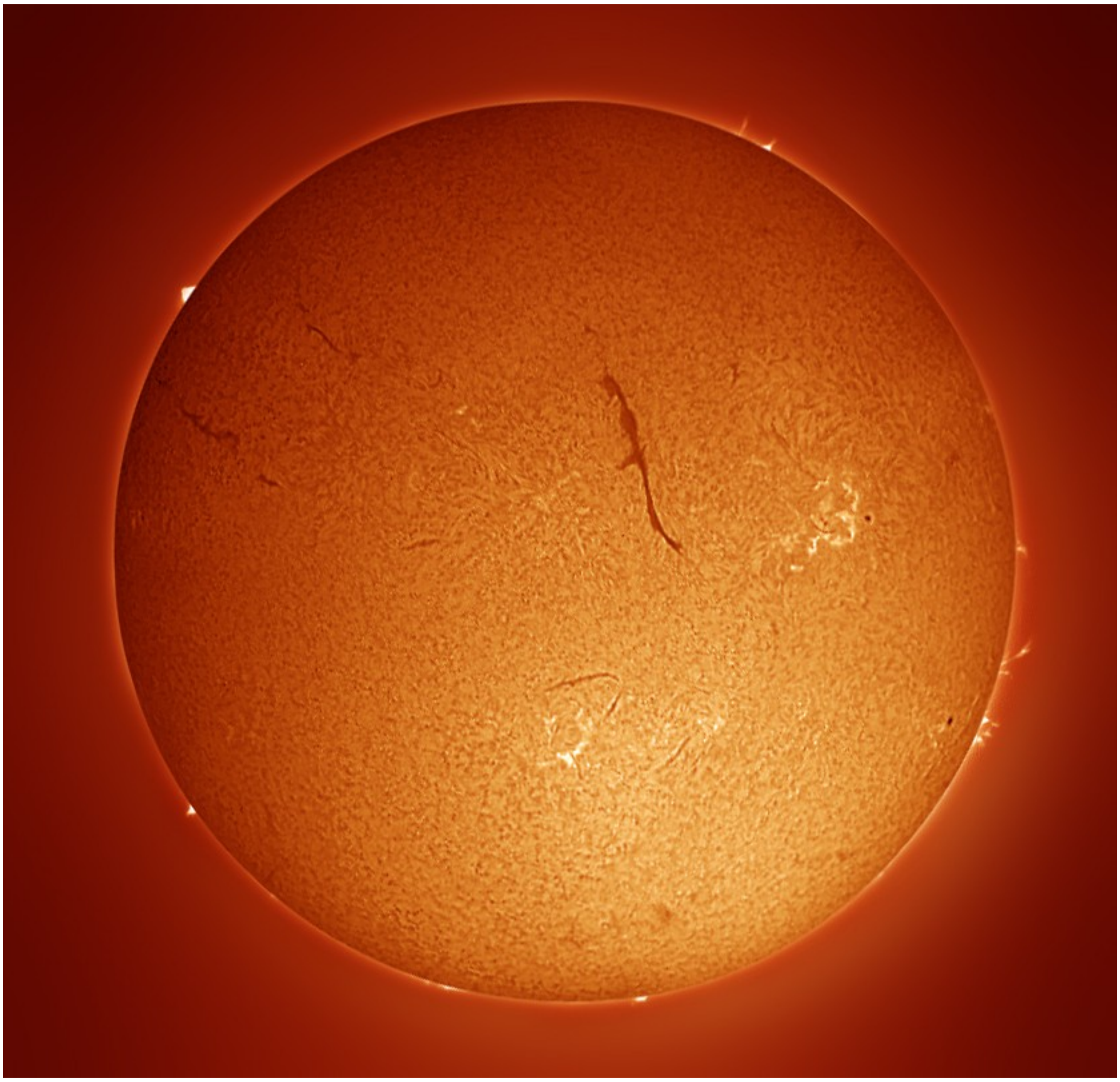
Our Sun captured on 28 September, showing the correct orientation (North is up).

**Hardware:**

Skywatcher EQ6 Pro. telescope mount (Synscan)
Lunt LS35THa Hydrogen-alpha telescope
Imaging Source DMK 21AU618 A.S. Camera

**Software:**

Skymap Pro. 9 (remote computer telescope control)
Lucam Recorder (image acquisition)
Autostakkert ll (alignment and stacking)
Registax v6 (wavelets function)
Adobe Photoshop CS II (combining solar disc and prominences, plus colour adjustments)



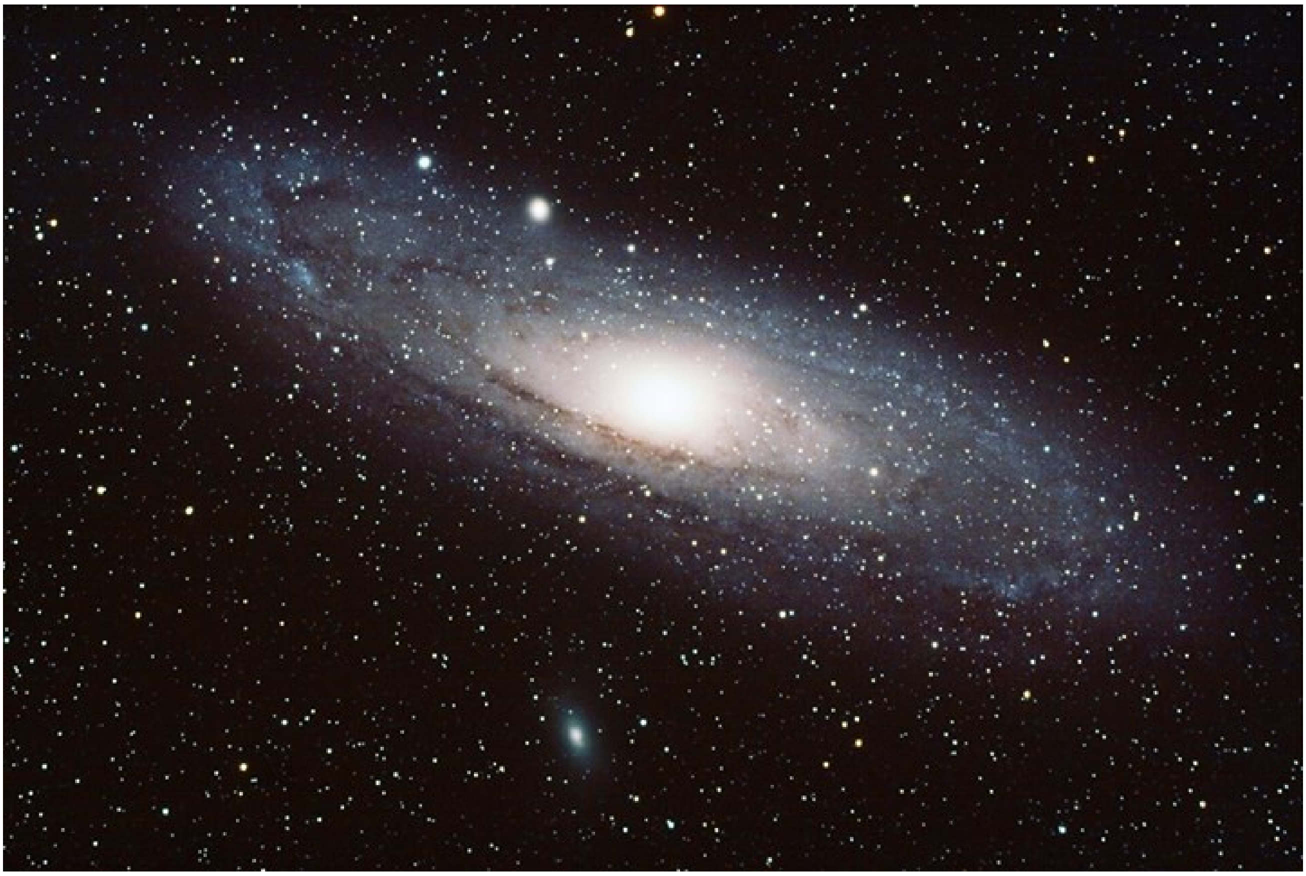
Here's an image of Messier 31, the Andromeda Galaxy, captured on 30 October at the Autumn Kielder star-camp.

**Equipment:**

HEQ5 Pro. mount
80mm ED refractor
Skywatcher field flattener
Astro-modified Canon 1000D camera
Guiding: William Optics ZS66, QHY5

**Exposures taken:**

15 lights × 4 mins. @ ISO 1600, 8 darks, 10 flats.



GENERAL ARTICLES

## Some thoughts on gravity and tides
## *Part 2: Orbits, rotation and tides*

***Ray Brown***

Part 1 (*Transit, October* 2013) concerned some consequences of Newton's Law of Gravitation. Newton's other famous contribution to science was his Laws of Motion, with which, I assume, the reader is familiar.

When a mass is whirled around on the end of a string, it is the tension in the string that prevents the mass from shooting off in what would be a straight line were it not for the force of gravity, which would cause it eventually to fall to Earth. The tension is called a **centripetal force**. All orbiting objects rely upon a centripetal force. In the case of the Bohr model of negatively-charged electrons orbiting the positively-charged nucleus of an atom, the centripetal force is electrostatic in nature. Orbiting astronomical bodies are held in their orbits by a centripetal force that is gravitational and obeys Newton's Law of Gravitation.

It is easy to show mathematically that for an astronomical body of mass *m* moving in a circular orbit of radius *r* with an angular velocity $\omega$, measured in radians per second ($\pi$ radians are equal to 180°), the centripetal force required is

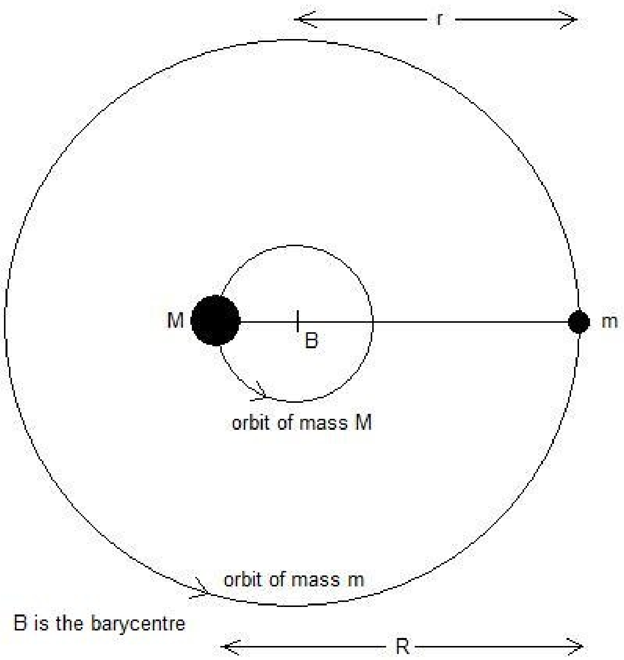
$$F = mr\omega^2 = mv^2/r \qquad (1)$$

where $v$ (= $r\omega$) is the orbital speed. This force is equal to (indeed *is*) the gravitational force

$$F = GmM/R^2 \qquad (2)$$

where $M$ is the mass of the second body, which provides the gravitational attraction, and $R$ is the distance between the two centres of mass of the pair of bodies. As in the case of a balanced see-saw, the two bodies orbiting one another obey the equation

$$mr = M(R - r) \qquad (3)$$

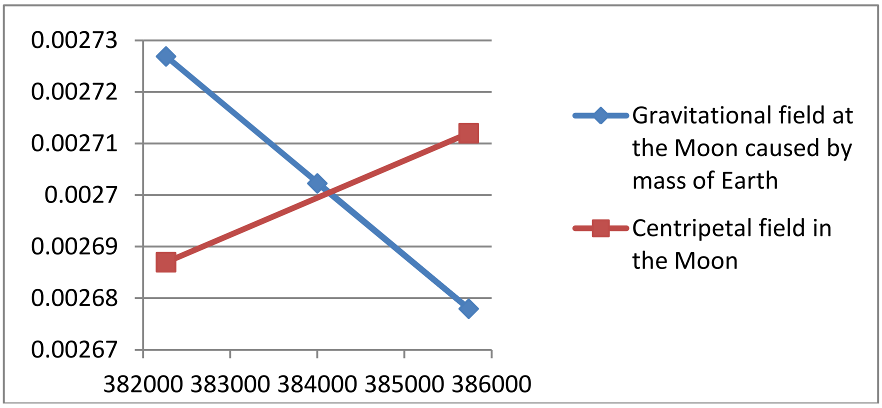



By eliminating *r* from equations (1), (2) and (3), we obtain equation (4):

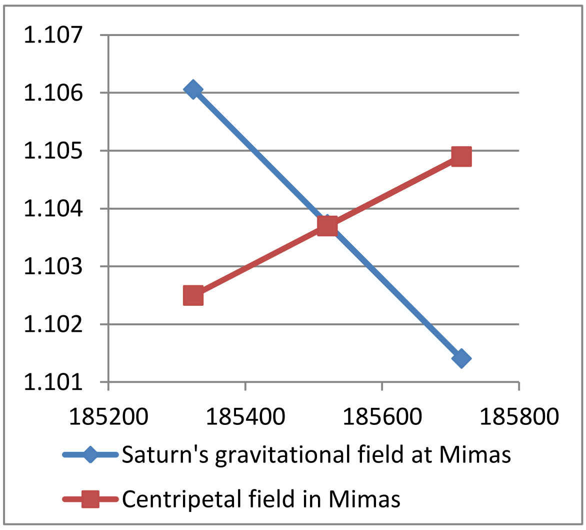
$$R^3\omega^2 = G(M+m) \qquad (4)$$

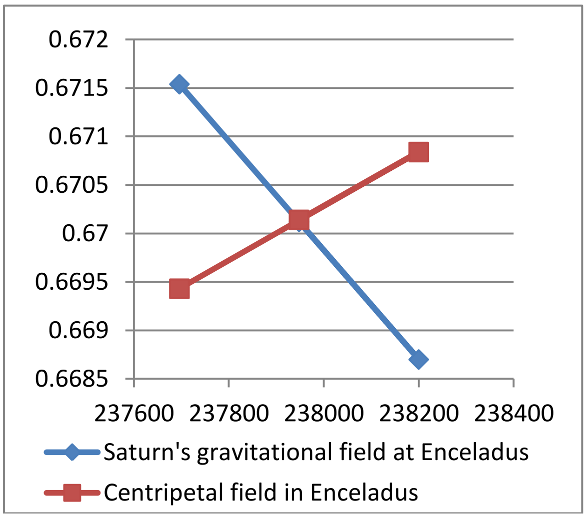
which is an expression of **Kepler's third law** (N.B. the orbital period $P = 2\pi/\omega$).

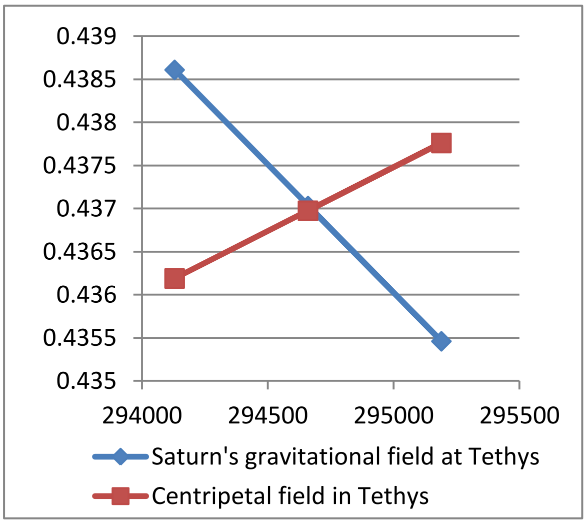
In Part 1, we saw how the *variation* of gravitational force with distance within a body tends to distort its shape; a sphere can be stretched to a prolate ellipsoid. However, in the case of an orbiting satellite whose spin is synchronous (e.g. our Moon, which always presents essentially the same face to Earth), then the internal deforming (tidal) force within the satellite has an additional contribution. With increasing distance from the centre of the orbit (the **barycentre**), not only does the provided gravitational force decrease but the required centripetal force increases. Although for the centre of mass of the satellite as a whole the centripetal force is exactly provided by the gravitational attractive force, there is a disparity between the two field strengths within the satellite at other distances from the barycentre. Equations (1) and (2) allow us to calculate and plot a graph for our Moon of the centripetal and gravitational field strengths (in newtons per kg) *vs.* distance (in km) from Earth.

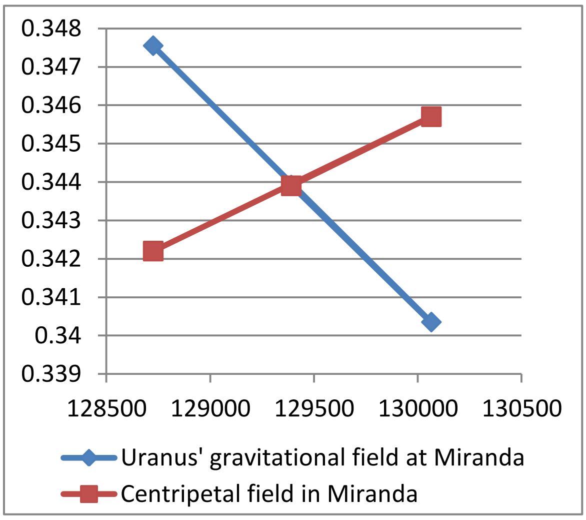



It is the difference between the gradients of the required centripetal field and the gravitational field provided by the mass of Earth that gives rise to **deformation tension** within the Moon. We can compare this graph with corresponding data for synchronous moons of Saturn and Uranus. (All fields have units of newtons per kg and all planet–moon distances are in km.)



As stated in Part 1, while deformation is not obvious from the shape of our Moon, it is discernible in some of the synchronous satellites of Saturn and Uranus. Data shown here indicate that the external field strengths in those satellites are two orders of magnitude greater than in our Moon. The contrast in the values of the gradients of field strengths is even greater. Furthermore, the mass of the Moon being some 81 times less than the Earth mass, field variations tending to cause distortion in Earth are considerably less even than those in the Moon, so that the stretching effect on those four moons of the outer planets is some $10^4$ to $10^5$ times greater than that which causes our ocean tides on Earth.

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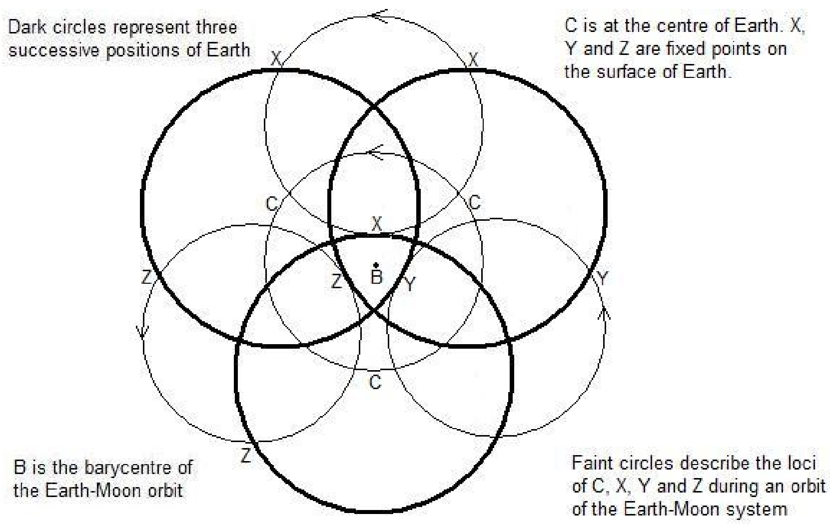
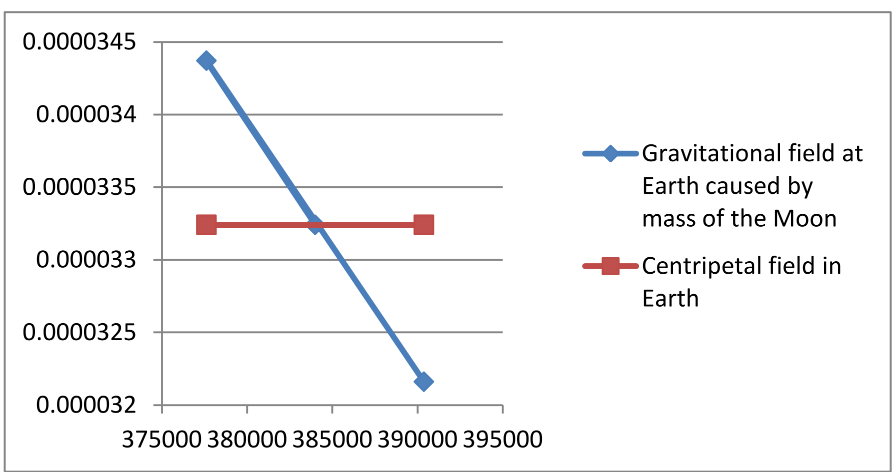
Unlike the Moon, the rotation of Earth is not synchronous; its rotation on a daily basis is not related to its monthly orbit around the Moon–Earth barycentre (which is actually some 1700 km *below* the surface of the Earth). So, as far as the Earth–Moon system is concerned, Earth does *not* rotate. Consequently, every location on and in Earth effectively has exactly the same magnitude of orbital radius as has the Earth's centre about the barycentre. So the centripetal force due to interaction with the Moon is uniform throughout Earth.




*Field strengths (N kg$^{-1}$) vs. Distance (km) from the Moon*

However, the gravitational field caused by the Moon does vary across Earth. Earth's surface is mainly covered with liquid water. Its low viscosity and consequent mobility allow it to respond to deforming forces, in particular that arising from variations in the gravitational field experienced by Earth as a result of its proximity to the Moon, the planets and the Sun. By far the major contribution to that gravitational field is from the Sun, which has much the larger mass, but the major contribution to the *gradient* or *variation* in the gravitational field is made by the Moon. Despite its relatively low mass, the proximity of the Moon to Earth enables its contribution to the gradient to exceed that of the Sun by a factor of more than two.

Although the masses of the Sun and Moon are respectively $2 \times 10^{30}$ kg and $7.35 \times 10^{22}$ kg, the respective mean distances from Earth are $1.496 \times 10^{8}$ km and $3.84 \times 10^{5}$ km.

As $F = Gm_E m_2/r^2$, then differential calculus gives $dF/dr = -2Gm_E m_2/r^3$ and it is $dF/dr$ which determines the magnitude of the tidal effect.

So the tidal contribution of the Moon is greater than that of the Sun by the factor

$$(1.496 \times 10^{8} / 3.84 \times 10^{5})^{3} \times (7.35 \times 10^{22} / 2 \times 10^{30}) = 2.2$$

The distribution of water on the surface of the Earth is influenced by several factors. Apart from the obviously dominant topography of the land masses, there is the variation with latitude of that centripetal force which arises from Earth's spin (i.e. the equatorial bulge effect) and the gravitational field gradients of the Moon and the Sun. The other planets have relatively negligible effects. Ocean tides result from two main phenomena: the Earth's daily rotation and the changing arrangement of the Sun, Earth and Moon with monthly periodicity.

Tides are determined by combined effects of the field gradients of the Moon and the Sun, both of which act to deform the Earth from a sphere to a prolate ellipsoid (soccer ball to rugby ball shape). The greatest effects that produce so-called 'spring' tides occur on an approximately fortnightly basis when the Sun, Earth and Moon are roughly aligned; then the gradients of the gravitational fields provided by the Sun and the Moon reinforce one another. Spring tides alternate weekly with 'neap' tides, which occur when the Sun and the Moon compete to drag the oceans in different directions. Spring tides have the largest extreme difference in water levels between high water and low tide, which occurs approximately 6 hours after high tide – i.e. when Earth has rotated a further 90° on its axis. During a 24-hour day there are two high tides and two low tides. Several factors, such as the eccentricities of the orbits of the Moon around Earth and of Earth around the Sun, produce second-order effects on the tidal patterns over longer periods – e.g. spring-tide amplitudes are most extreme when the Moon is near the perigee.

The schematic diagrams shown on the next page are, of course, not drawn to scale!

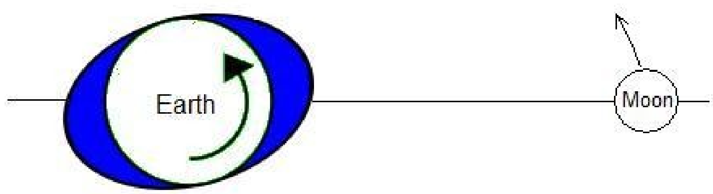
Spring tide

Neap tide

Neap tide

Spring tide

As Earth rotates, it drags its oceans with it, so the tidal bulge is pulled ahead of where it would be on a non-rotating Earth. So the attraction by the Moon acts as a braking force on the Earth's rotation. Newton's third law requires, therefore, that the bulge applies an accelerating force on the Moon in its orbit.




Consequently, each year, the rotation period of Earth is increasing (by $1.4 \times 10^{-5}$s), while the orbital speed of the Moon–Earth system rises accordingly. The distance between Earth and the Moon has been measured to be increasing by 3.8 cm per year. **Conservation of angular momentum**, a principle that follows from Newton's laws of motion, allows us to calculate what the values for the Earth–Moon distance and the orbital period will become when the spin of the Earth has slowed to the extent that an Earth day becomes as long as the orbital period – i.e. when spin-orbital synchronous coupling is attained by Earth. An estimate that considers only the Earth–Moon system in isolation predicts that the length of an Earth day will have increased by a factor of about 47 and that the Earth–Moon distance (treated as a circular orbit) will have increased from the present $3.84 \times 10^5$ Km to approximately $5.2 \times 10^5$ Km . However, as this condition would not be attained for billions of years, it will be pre-empted by other cataclysms, notably the evolution of the Sun into a red giant star.

Our government is supposed to favour 'renewable' energy sources. Whereas wind turbines produce power only when there is a wind, and solar PV justifies investment only on long, fine, summer days, the tides are a reliable and predictable source of energy that will be available well beyond the expected duration of the human species. Tidal barrages across the Severn and Solway estuaries could provide a significant contribution to meet the UK energy demand.

*Next month: Part 3 will discuss escape velocities, planetary atmospheres and black holes.*

# Brief comments on October's *Transit*

*John Crowther*

The footnote last month on the description of the Whipple Museum in Cambridge is relevant to my own short article in the same issue, for astro-poetry does come down from past societies and cultures. We must also include music and verse such as is found in the old hymn 'The spacious firmament on high'.

Going on to Michael Roe's 'grim' article 'The end of space exploration', here are a few thoughts.

Going to the Moon may be likened to a walk to the corner shop, whereas a journey to Mars would be a full marathon. What about getting to the next star? A round-the-world hike. So did the average person in the 1970s really understand the vast distances and energies needed to go beyond the Moon – and is Mars, a cold desert, worth sending humans to?

We are reminded of a young child very ready to eat a big meal. Its mother says, 'Your eyes are bigger than your stomach.' His older brother says, 'It's because your stomach thinks your throat's cut.' We may get there, but not for a very long time.

## THE TRANSIT QUIZ

## Answers to October's quiz

*Every answer starts with the letter I. The questions were in very rough order of increasing difficulty.*

1. A collective term for Mercury and Venus, as distinct from Mars and more distant planets. **Inferior planets (that is, planets whose orbits lie within that of the Earth).**
2. The very bright but short-lived glint off a panel of a particular kind of communications satellite that can be predictably viewed along a thin strip on Earth. **Iridium flare (see www.satobs.org/iridium.html).**
3. The hypothesis introduced in 1981 by Alan Guth, now part of the standard cosmological model. **Inflation.**
4. Saturn's 'yin-yang' satellite. **Iapetus, of which half is very dark with an albedo of about 0.05, and half bright with an albedo of about 0.5.**
5. The most volcanically active body in the Solar System. **Io, the innermost Galilean satellite of Jupiter.**
6. A catalogue of nebulae and clusters prepared over 100 years ago by John Dreyer as a sequel to his 1888 New General Catalogue (NGC). **Index Catalogue (IC), produced in two parts in 1895 and 1908.**
7. The disappearance of a star or planet behind the Moon's leading limb at an occultation. **Immersion.**
8. The total amount of radiant energy from the Sun falling on a body, per unit area perpendicular to the direction of the Sun, in unit time. **Insolation.**
9. The second asteroid to be imaged in close-up by a passing spacecraft (Galileo). **Ida.**
10. The Lunar Module pilot on the Apollo 15 mission, and the first Moonwalker to die. **James Irwin (1930–91).**

## November's quiz

*Every answer starts with the letter J. The questions are in very rough order of increasing difficulty.*

1. NASA's centre of excellence for deep-space systems, in Pasadena, California.
2. The planned future successor to the Hubble Space Telescope.
3. Asteroid number 3, discovered in 1804.
4. The largest facility in the world designed specifically to operate at submillimeter wavelengths, and situated on Mauna Kea, Hawaii.
5. The tenth Astronomer Royal, who arranged the move of Greenwich Observatory to Herstmonceux in Sussex.
6. The name given by John Herschel to the brilliant open cluster NGC 4755 in the constellation Crux.
7. The international unit of flux density, equal to $10^{-26}$ watts per square metre per hertz.
8. The number of days that have passed since noon GMT on 1 January 4713 BC.
9. The French inventor of the spectrohelioscope.
10. The size of a nucleon (essentially a hydrogen atom) is defined as 1 fermi, and is equal to $10^{-13}$ cm. What name has been suggested (by Richard Tolman) for the time required for light to travel a distance of 1 fermi?